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TR 68-22

AD834227

TECHNICAL REPORT NO. 68-22

SHORT-PERIOD MULTICOMPONENT STRAIN SYSTEM

Quarterly Report No. 1, Project VT/8704

16 February to 31 May 1968

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TECHNICAL REPORT NO. 68-22

SHORT-PERIOD MULTICOMPONENT STRAIN SYSTEM
Quarterly Report No. 1, Project VT/8704
16 February to 31 May 1968

by

R. C. Shopland

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

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Acknowledgement

This research was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, under Project VELA-UNIFORM, and accomplished under the technical direction of the Air Force Technical Applications Center under Contract No. F33657-68-C-0948.

GEOTECH
A TELEDYNE COMPANY
3401 Shiloh Road
Garland, Texas

15 June 1968

IDENTIFICATION

AFTAC Project No.	VELA T/8704
Project Title:	Short-Period Multicomponent Strain System
ARPA Order No.	624
ARPA Program Code No.	8F10
Name of Contractor:	Teledyne Industries, Inc. Geotech Division
Contract No.	F33657-68-C-0948
Effective Date of Contract:	16 February 1968
Amount of Contract:	$104,000
Contract Expiration Date:	15 February 1969
Project Manager:	R. C. Shopland, 214 271-2561

CONTENTS

ILLUSTRATIONS

ABSTRACT

A five-component system of matched short-period strain and inertial seismographs at Wichita Mountains Observatory (WMO) was expanded to include a three-component system of matched long-period strain and inertial seismographs for recording large magnitude earthquakes. A data library and quality assurance procedure has been established. Calibration of the vertical strain seismometer with both a short rod and a rod of standard length (18 m) shows an apparent mechanical signal loss of 22 percent and a corresponding phase change as large as four degrees. A series of improvements has reduced the noise level of the long-period strain seismographs substantially. A site other than Garland, Texas, is being considered for noise suppression tests with a combination of vertical strain and inertial seismographs. A recent study of the effect of low ratio of seismic signal to system noise on coherence has been made. From this study, it is concluded that the possibility of suppressing microseisms in the region of 1 Hz with a combination of vertical strain and inertial seismographs cannot be evaluated unless either the generator constant of the vertical strain seismometer is increased, or tests are conducted at a site where the seismic noise level at 1 Hz is higher than at WMO.

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SHORT-PERIOD MULTICOMPONENT STRAIN SYSTEM
Quarterly Report No. 1, Project VT/8704
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1. INTRODUCTION

This report discusses evaluation of a system of strain and inertial seismographs having matched amplitude and phase reponses in the frequency range 0.01 to 10 Hz. It is submitted in compliance with Sequence Number A008 of Contract Data Requirements List, Contract F33657-68-C-0948. The Statement of Work is included as Appendix 1.

During the reporting period, the major accomplishments were as follows:

a. A new electromagnetic (EM) calibrator was installed in the vertical strain seismometer in the steel-cased borehole (SZ1) and tests were run to determine the amount of signal loss in the seismometer.

b. A single-coil EM calibrator similar to the one in the vertical strain seismometer was designed for the horizontal strain seismometer. An engineering model was fabricated and laboratory tests were started.

c. Tests were started to determine the effect of the shallow-strain environment on operation of the long-period (LP) strain seismographs at the Wichita Mountains Seismological Observatory (WMSO).

d. A three-component system of matched long-period strain and inertial seismographs was installed at WMSO to record large magnitude events.

e. Work was essentially completed on a study to determine the source of low coherence among strain and inertial seismographs for microseisms at frequencies near 1.0 Hz.

2 OPERATION (TASK 1a)

Initial plans called for operation of short-period (SP) strain and inertial seismographs on a routine basis and operation of one or two LP strain and companion LP inertial seismographs on a test basis. The operational requirement has now been expanded to include the operation of a three-component set of matched LP strain and inertial seismographs to record large magnitude earthquakes. The LP set was fully operational on 31 May 1968. SP and LP frequency response curves are described in Technical Report No. 68-3. Recording formats are discussed below.

2.1 SHORT-PERIOD SEISMOGRAPHS

Short-period data are recorded on WMO magnetic-tape recorder No. 3 and WMO Develocorder No. 7 as indicated below.

WMO magnetic-tape recorder No. 3

Channel No.	Short-period strain primary
1	BCD station time
2	Short-period north inertial (SPN)
3	Short-period east inertial (SPE)
4	Short-period north strain (SNS)
5	Short-period east strain (SES)
6	Short-period northeast inertial (SPNE)
7	Compensation
8	Short-period northwest inertial (SPNW)
9	Short-period northeast strain (SNES)
10	Short-period northwest strain (SNWS)
11	Short-period vertical strain in plastic-cased borehole (SZS_2)
12	Short-period vertical inertial (SPZ)
13	Spare test channel
14	Voice comment

WMO Develocorder No.7

Trace No.	Short-period strain primary
1	Short-period north inertial (SPN)
2	Short-period north strain (SNS)
3	Summation of SNS and SES (Σ SNS, SES)
4	Short-period east strain (SES)
5	Short-period east inertial (SPE)
6	Short-period north inertial (SPN)
7	Short-period vertical inertial (SPZ)
8	Spare test channel
9	Short-period vertical strain in plastic-cased borehole (SZS_2)

Trace No.	Short-period strain primary
10	Short-period northeast inertial (SPNE)
11	Short-period northeast strain (SNES)
12	Summation of SNES AND SNWS (Σ SNES, SNWS)
13	Short-period northwest strain (SNWS)
14	Short-period northwest inertial (SPNW)
15	Anemometer (Wind)

2.2 LONG-PERIOD SEISMOGRAPHS

During most of the reporting period, LP seismographs were recorded on WMO Develocorder No. 5 on a test basis. By 31 May 1968, a calibrated set of three-component strain and matched inertial seismographs were in operation on film and magnetic tape in the format shown below. The LP inertial signals are obtained from WMO vault No. 7. The seismometer and galvanometer in each circuit are very closely coupled; consequently, the inertial responses do not closely match the strain responses. The CT designation indicates a coordinate transformation, wherein the north and east inertials in vault 7 are electrically transformed into northeast and northwest components to conform with the orientation of the strain seismographs.

WMO magnetic-tape recorder No. 2

Channel No.	Long-period strain primary
1	BCD station time
2	Long-period northeast strain low-gain ($SNEL_{Lo}$)
3	Long-period vertical inertial low-gain (ZLL_{Lo})
4	Long-period northeast strain (SNEL)
5	Long-period northwest inertial, coordinate transformed, Vault No. 7 (LPNW/CT)
6	Long-period vertical strain (SZL)
7	Compensation
8	Long-period northeast inertial, coordinate transformed, Vault No. 7 (LPNE/CT)
9	Long-period northwest strain (SNWL)
10	Long-period vertical strain low-gain (SZL_{Lo})
11	Long-period northeast inertial, coordinate transformed, Vault No. 7, low-gain ($LPNE/CT_{Lo}$)
12	Long-period northwest strain low-gain ($SNWL_{Lo}$)
13	Long-period vertical inertial (ZLL)
14	WWV

WMO Develocorder No. 5

Trace No.	Long-period strain primary
1	Short-period microbarograph (SP/MB)
2	Long-period northeast inertial, coordinate transformed, Vault No. 7 (LPNE/CT)
3	Long-period northeast strain (SNEL)
4	Long-period microbarograph (LP/MB)
5	Long-period vertical inertial (ZLL)
6	Long-period vertical strain (SZL)
7	Long-period northwest inertial, coordinate transformed, Vault No. 7 (LPNW/CT)
8	Long-period northwest strain (SNWL)

2.3 MAINTENANCE

A lightning storm on 21 May burned out a coil on the EM calibrator on the vertical strain seismometer (SZ1). It also damaged a Harris galvanometer in the SNWL channel and an operational amplifier in the TR-10 Analog Computer used for coordinate transformation of WMO LP inertials. A new coil for the EM calibrator was ordered; a Harris galvanometer was borrowed while the damaged unit is being repaired; and the damaged operational amplifier was repaired in the field.

A lightning storm on 31 May caused outages on LP inertials and the microbarograph in the strain vault. Calibrator coils on two horizontal strain calibrators were burned out, and a lead wire on a third calibrator was burned out. All calibrators are protected by gas-diode lightning protectors mounted at ground surface level at the entrance to the tank vaults that house the calibrators.

3. STRAIN DATA LIBRARY (TASK 1b)

3.1 ANALYSIS OF SEISMIC DATA

The Strain Data Library consists of 16-mm film seismograms, magnetic-tape recordings, and information concerning recorded earthquakes, microseisms, and record quality.

The film seismograms are analyzed each week using the following procedures: Recorded earthquakes are noted by logging the 'P' arrival time, type of event, largest amplitude within the first three cycles, and the period. All phases following the 'P' arrival are logged similarly. Later, the earthquakes are associated with epicentral data published by either LASA or USC&GS. Remarks regarding the microseismic activity of each day are also included.

This analysis is not intended to be rigorous, performed for the sole purpose of detecting earthquakes, but rather a method of keeping a library of daily seismic occurrences at WMO that may be used in strain research.

3.2 QUALITY ASSURANCE

Since the strain program at WMO is not strictly a routine operation, nor is strain analysis performed at the station, the following quality assurance is implemented. Calibration amplitudes measured at WMO are checked for accuracy and correct timing. Outage time is recorded along with non-seismic occurrences such as electrical spikes. Remarks regarding the presence of wind-generated noise are also logged.

3.3 STORAGE PROBLEM

At the start of the present project, 201 strain magnetic-tape records from WMO Tape Recorder No. 3 were retained at Garland, Texas, for strain studies. A list of the records was mailed to the VELA Seismological Center on 7 February 1968. By the end of this project, 366 additional tapes of SP data and approximately 36 tapes containing LP data will be acquired. It is recommended that provision be made for dubbing selected seismic events and samples of background noise to free the tape for other use and to eliminate a storage problem. To be effective, it is considered necessary to record approximately 265 regional and teleseismic events and 75 local and near regional events.

4. DETERMINE OPTIMUM OPERATING CHARACTERISTICS (TASK 1c)

4.1 MATCHING OF LP STRAIN AND INERTIAL SEISMOGRAPHS

With the recent added requirement for operation of a three-component LP strain and inertial system at WMO, a shortage of LP instruments has necessitated the use of signals from WMO's operational LP inertial seismographs in vault No. 7. Because the WMO inertial seismometer and galvanometer are closely coupled, the inertial system is not matched precisely to the strain seismographs. Arrangements will be made to reduce the coupling effect; otherwise, separate LP inertial instrumentation will have to be installed in the strain vault.

North and east horizontal LP inertial signals from vault No. 7 are coordinate transformed to operate in combination with the northeast and northwest strain seismographs. The directional stability of the coordinated transformed (CT) channels depends upon the relative gains between the two orthogonal seismographs that comprise the CT channel. A preliminary evaluation of the relative gain stability of the component seismographs indicates that satisfactory directional stability exists.

As an approximate measure of the proper operation of the CT channels, Rayleigh wave amplitudes measured on the north and east LP components were transformed mathematically to NE and NW components and compared with measurements on the CT channel. This procedure yielded satisfactory results. Another procedure involves comparing the great circle azimuth of the reported epicenter and the azimuth of the surface waves computed from measurements on the CT channels; however, the accuracy of this procedure is affected by deviations of the signal from a great circle path.

The small experimental transducer on the northwest strain seismometer has sufficient sensitivity for operation at the present magnifications. However, because the ratio of seismic background to electronic noise is marginal, it may be necessary to transfer the standard, large moving-coil transducer from the east strain seismometer to the northwest seismometer.

To achieve the present degree of matching of strain and inertial channels, two LP matching filters (Model 28900-02) were fabricated and installed in the strain channels on 18 May 1968. Again, close matching of strain and inertial channels cannot be achieved unless the seismometer-galvanometer coupling factor in the WMO LP inertial seismographs is reduced.

5. STRAIN APPLICATIONS (TASK 2a)

5.1 SUPPRESSION OF COMP'EX NOI.E FIELDS

At present, a study of the character of the noise field is underway. The change in the amplitude spectrum and the directionality is being measured. The change in suppression of noise as a function of time with both the vertical inertial-vertical strain and vertical inertial-crossed strain combinations are being evaluated. The stability of narrow windows in the spectrum of suppressed noise is being investigated also.

A study to obtain quantitative estimates of P enhancement attainable through the noise suppression technique is nearly complete. In this study, six samples of microseisms from a six-month period were selected randomly from records obtained during periods of reliable recording and low-wind speeds. The number of samples was limited to six to limit computer costs. Both orthogonal strains and vertical strains were combined with vertical inertial data through a 90-degree phase compensator. This study is nearly complete.

5.2 THE PROBLEM OF LOW COHERENCE IN THE REGION OF 1 HZ

Coherence computed between recordings of microseisms by the two pairs of orthogonal (crossed) strain seismographs at WMO has been observed to be low near 1.0 Hz. The low coherence, in addition to correlating with a spectral low for microseisms at 1 Hz, also correlates with a spectral peak in the system noise.

In a recent study, theoretical and empirical measurements of coherence were made between two sets of crosses-strain seismographs as a function of the ratio of seismic signal (S) to system noise (N). A P-wave signal was used to verify the applicability of Bendat and Piersol's (1966) theoretical realtionship between coherence and S/N ratio. The equality between empirical and theoretical curves of coherence as a function of S/N ratio held at high values of S/N; however, it deteriorated when microseismic signals were used, since the theoretical equation does not allow for the noise term in the numerator of the ratio S/N.

It is concluded from this investigation that the low coherence for microseisms in the region of 1 Hz is caused by a low ratio of microseismic

signal-to-system noise. It is important to note that the coherence between two strain or inertial recordings can be evaluated for microseisms only by increasing the generator constant of the strain transducers or by decreasing the system noise. In effect, the possibility of suppressing microseisms in the region of 1 Hz using combinations of strain and inertial seismographs cannot be evaluated unless the S/N ratio is increased. Lacking a change in instrumentation, application of seismic noise suppression techniques in the region of 1 Hz will be restricted to locations where higher level noise exists at 1 Hz.

Data and illustrations supporting these conclusions will appear in a later report.

5.3 IDENTIFICATION OF WAVE TYPES

A number of good quality events for a study of wave identification are now available. Tape playouts are being inspected to ensure the suitability of selected signals. The signals will serve as a basis of a study to identify and enhance different wave types. Measured strain will be compared with theoretical strain; strain and inertial responses to basic wave types and principal earthquake phases will be compared using measurements of coherence, phase, spectra, and transfer functions.

5.4 THE SURFACE ANOMALY

Theoretical determinations of amplitude and phase of P and SV were made using a 4.5-meter low-velocity layer at the surface in an effort to explain the anomalies observed in the Lg phase of regional events. Large changes in phase and amplitude were obtained. Additional adjustment of the earth model will be made in an effort to match empirical data. Initial tests are related to the phase of the P wave as a function of angle of incidence. The output of summed orthogonal horizontal strains will be compared with the vertical strain. P-wave amplitudes from large events will be equated so that minimum residuals of the sum of the vertical and crossed-horizontal strain outputs will reflect the magnitude of the phase difference.

6. IMPROVEMENT OF INSTRUMENTS (TASK 2b)

6.1 VERTICAL STRAIN SEISMOMETER

6.1.1 Electromagnetic (EM) Calibrator

Minor changes were made in the design of the EM calibrator. A unit was fabricated for use in the vertical strain seismometer in the steel-cased borehole (SZ1) and was installed on 16 April. Using the calibrated variable-capacitance transducer (VCT) in the strain transducer section to monitor calibrator output, the EM calibrator constant was measured in the borehole at WMO with the strain transducer package attached directly to the EM calibrator. The test was repeated with the seismometer in its normal operating condition using an 18.6 m interval between anchors. Theoretical and measured calibrator constants are listed below:

Case	EM calibrator constant (mμ/mA)	Condition
I	2.07	Theoretical (excluding mechanical losses within the EM calibrator)
II	1.50	Measured with strain transducer directly connected to EM calibrator
III	1.17	Measured with seismometer in normal operating condition (18.6 m length)

Despite an apparent loss of 22 percent in seismometer output between Case II and Case III, as shown in figure 1, the seismograph phase response (figure 2) differs by not more than four degrees in the frequency band of interest. It is noted in figures 1 and 2 that the electrical stiffness introduced by the data-coil circuit has a small but measurable effect on the frequency response of the seismometer.

6.1.2 Investigation of Mechanical Signal Loss

Loss of motion due to stiffness in the O-ring where the rod enters the transducer package, will be investigated after performing the same tests with the seismometer in the plastic-cased borehole (SZ2). At present, the SZ2 seismograph gives a lower seismic background than SZ1 at the same magnification, indicating the possible existence of O-ring losses and/or friction in the transducer clamp. Additional guide springs are being added to the transducer package to guard against cocking of the transducer during the anchoring operation in the plastic borehole, since that borehole has a larger inside diameter than the steel-cased borehole.

6.2 HORIZONTAL STRAIN SEISMOMETER

6.2.1 EM Calibrator

A single-coil cylindrical EM calibrator was designed to replace the present double-coil calibrator on the horizontal strain seismometer. An engineering model was completed on 20 May and is now undergoing laboratory tests. Its motor constant and natural frequencies of vibration in the longitudinal and transverse mode will be measured. In field tests at WMO, motion will be measured at the calibrator and at the free end of the seismometer to measure mechanical losses in the seismometer. Three additional units will be built after the engineering model is field tested.

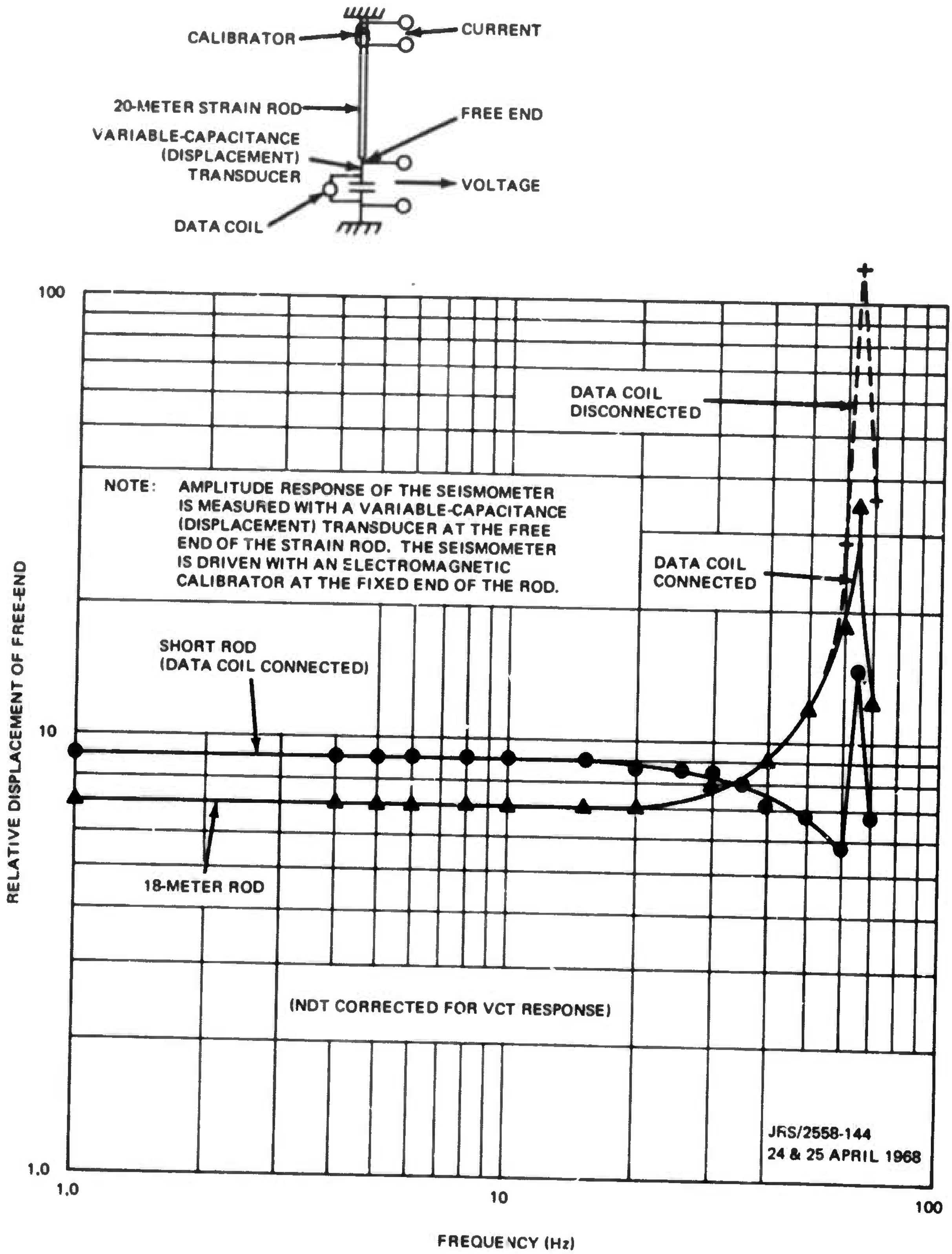

Figure 1. Relative displacement of the free end of the vertical strain seismometer as a function of frequency indicating an apparent seismometer mechanical loss of 22% when adding an 18-meter rod.

G 4156

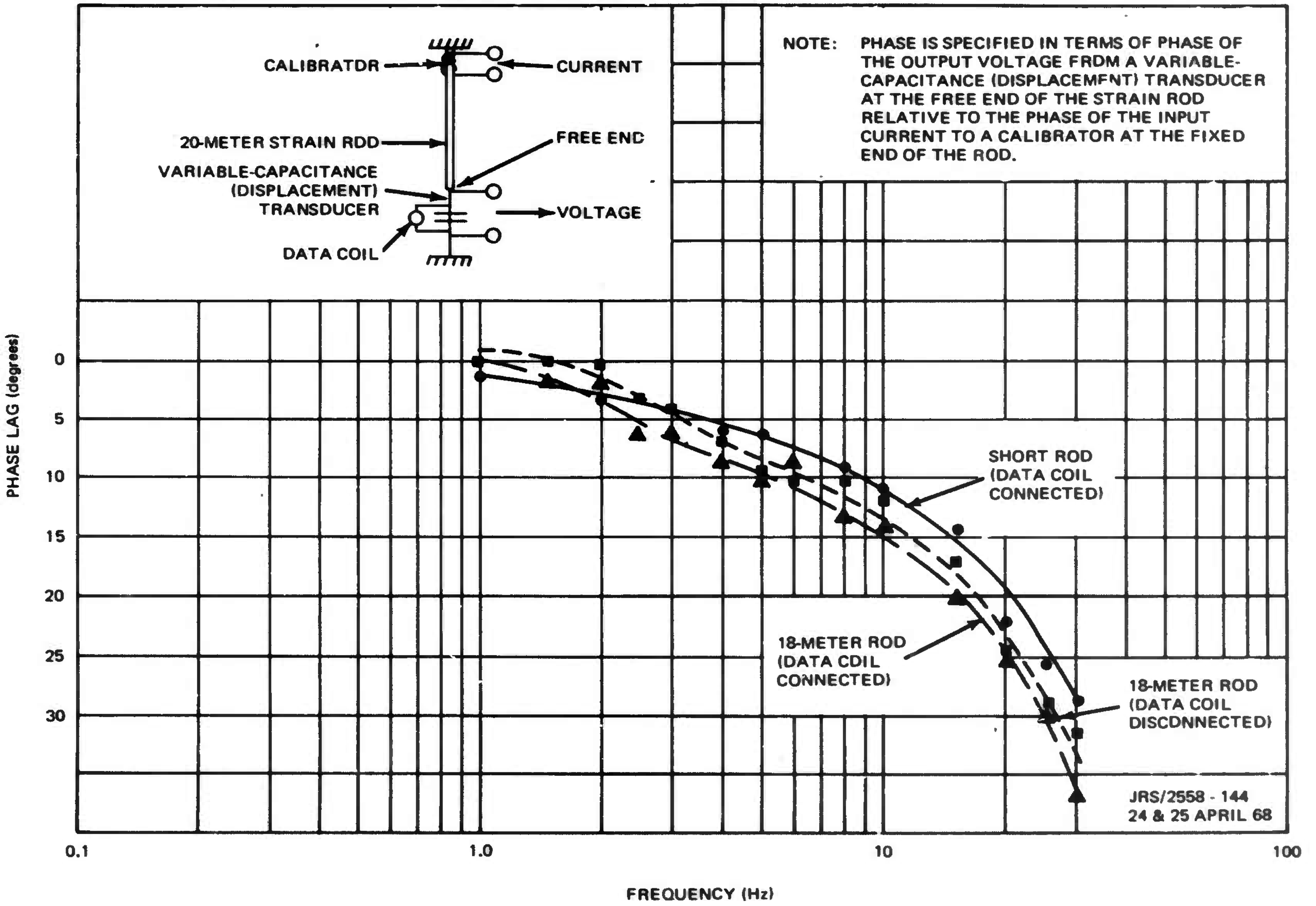

Figure 2. Phase response of the vertical strain seismomenter showing both the effect of adding the 18-meter rod and the effect of the electrical stiffness of the data coil circuit.

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6.3 LONG-PERIOD STRAIN SEISMOGRAPH IMPROVEMENTS

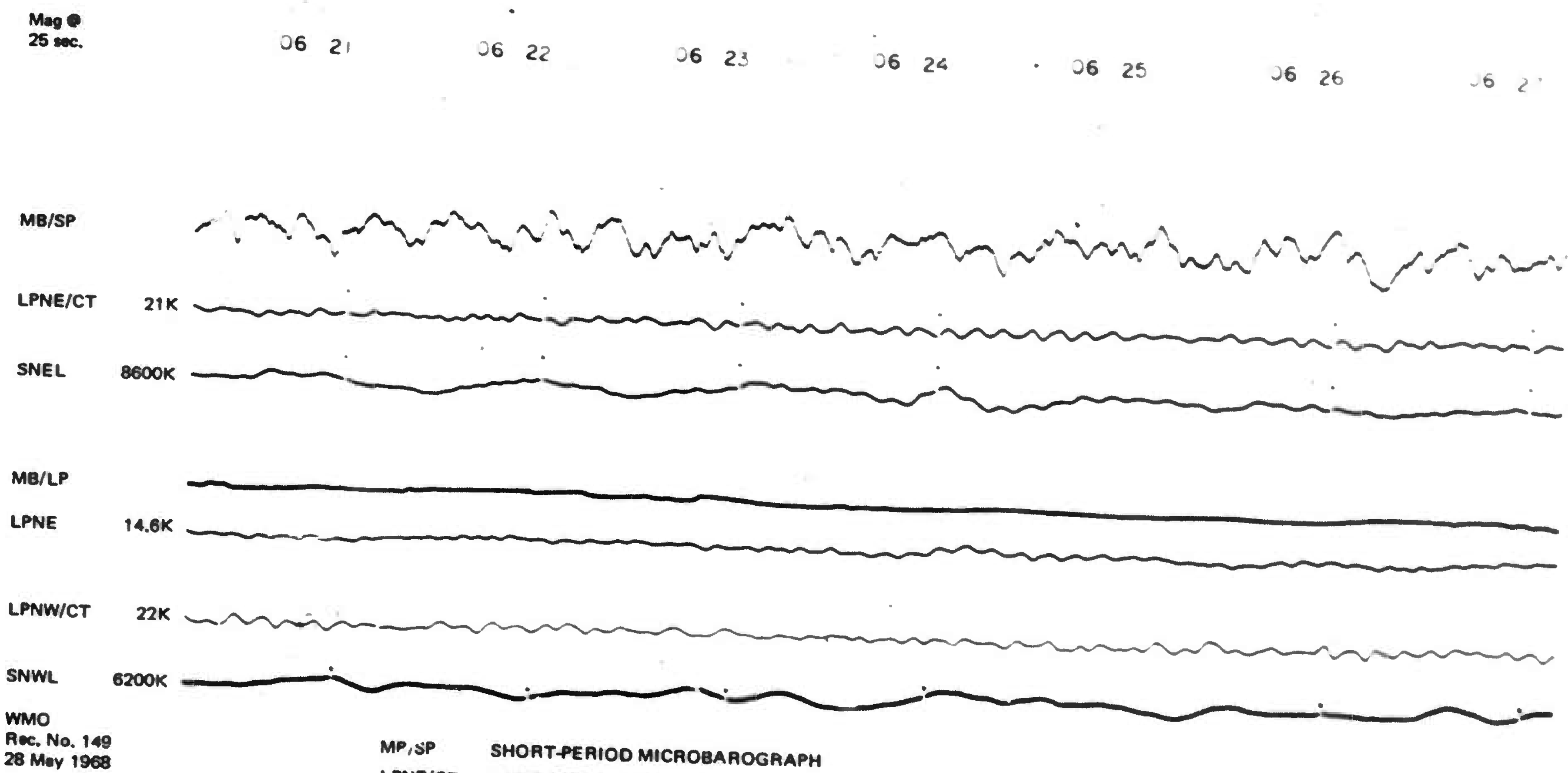
Long-period tests at WMO are directed toward gaining a better understanding of noise sources that limit usefulness of the LP strain seismographs in a shallow installation. Several steps, as discussed below, have been taken to reduce instrument noise.

At the start of this project (VT/8704) the north (N) and east (E) strain seismometers had large, velocity transducers, whereas the northeast (NE) and northwest (NW) seismometers had small, temporary, velocity transducers. The E seismometer developed a misaligned rod, and the N, a broken rod. Of the two remaining seismometers, the NE was in the best condition; therefore, the large moving-coil transducer on the N seismometer was transferred to the NE.

In a series of steps, the strain vault was resealed so that air pressure changes within the vault were reduced to a point where they did not correlate with strain output; a 1-meter aluminum extension tube in the NE leg was replaced by a section of quartz; the steel delta rods in the transducer were replaced by Invar rods to reduce mechanical noise; and a styrofoam convection shield was placed over the strain transducer. During periods of low wind, the noise level on the long-period northeast strain seismograph (SNEL) has been substantially reduced. As shown in figure 3, the noise level at periods exceeding 60 seconds is approximately 2 mm of trace motion at a strain magnification of 8600K (equivalent inertial magnification = 14K at 25 seconds, using a phase velocity of 3.0 km/sec).

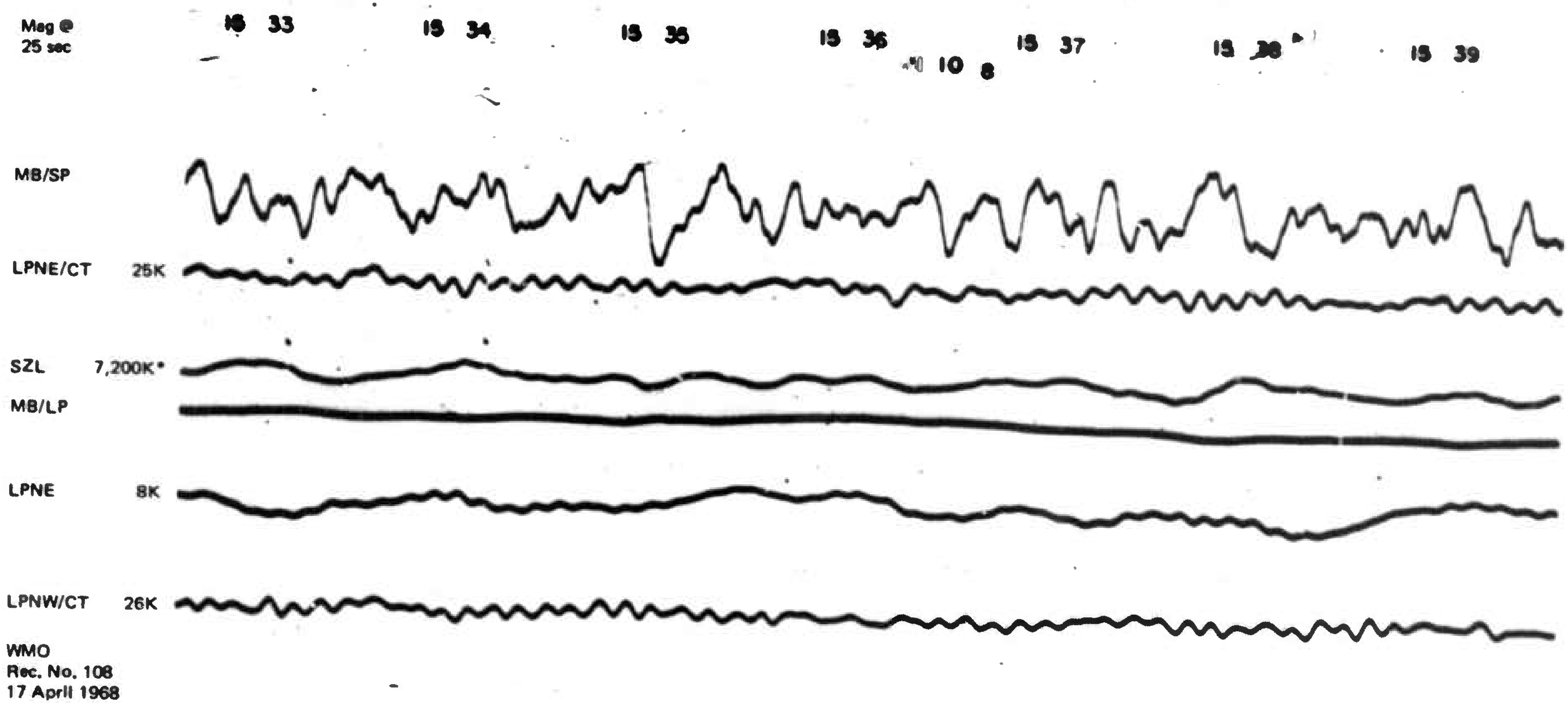
A LP horizontal inertial seismograph (LPNE) matching the frequency of SNEL was installed in the strain vault on 2 April. It is serving as a control instrument for SNEL and will also be used to measure ground-coupled pressure effects. Initally, the Model 8700A seismometer in the LPNE system was operated without a thermal shield. The background noise averaged 2 mm of trace motion at 25 sec and 10 mm at 100 sec at a system magnification of 11K at 25 sec. A styrofoam convection shield installed on 14 May reduced the instrument noise to the low level shown in figure 3.

The noise level on the vertical strain seismograph (SZL), which at one time limited magnification to approximately 0.1K, is now at a reasonable level due in part to installing a continuous 152-meter length of cable in steel conduit between the strain seismometer and the remote operational facility. As shown in figure 4 the maximum noise level is approximately 1-1/2 mm of trace motion at a strain magnification of 7200K at 25 sec. The maximum noise amplitudes occur at periods near 60 sec. The present degree of usefulness of SZL for recording large magnitude earthquakes is demonstrated in figure 5, which is a seismogram showing surface waves from a magnitude 5.6 earthquake at an epicentral distance of 108 degrees.



MP/SP	SHORT-PERIOD MICROBAROGRAPH
LPNE/CT	LONG-PERIOD NORTHEAST INERTIAL/COORDINATE TRANSFORMED, VAULT NO. 7
SNEL	LONG-PERIOD NORTHEAST STRAIN
MB/LP	LONG-PERIOD MICROBAROGRAPH
LPNE	LONG-PERIOD NORTHEAST INERTIAL
LPNW/CT	LONG-PERIOD NORTHWEST INERTIAL/COORDINATE TRANSFORMED, VAULT NO. 7
SNWL	LONG-PERIOD NORTHWEST STRAIN

Figure 3. Seismogram showing low instrument noise on the long-period strain and inertial seismographs in the strain vault.



MB/SP	SHORT-PERIOD MICROBAROGRAPH
LPNE/CT	LONG-PERIOD NORTHEAST INERTIAL/COORDINATE TRANSFORMED, VAULT NO. 7
SZL	LONG-PERIOD VERTICAL STRAIN
MB/LP	LONG-PERIOD MICROBAROGRAPH
LPNE	LONG-PERIOD NORTHEAST INERTIAL
LPNW/CT	LONG-PERIOD NORTHWEST INERTIAL/COORDINATE TRANSFORMED, VAULT NO. 7

Figure 4. Seismogram showing improved operation of long-period vertical strain seismograph (SZL). In previous tests (1964), severe long-period drifting limited SZL magnification to approximately 200K (equivalent inertial magnification = 0.1K).

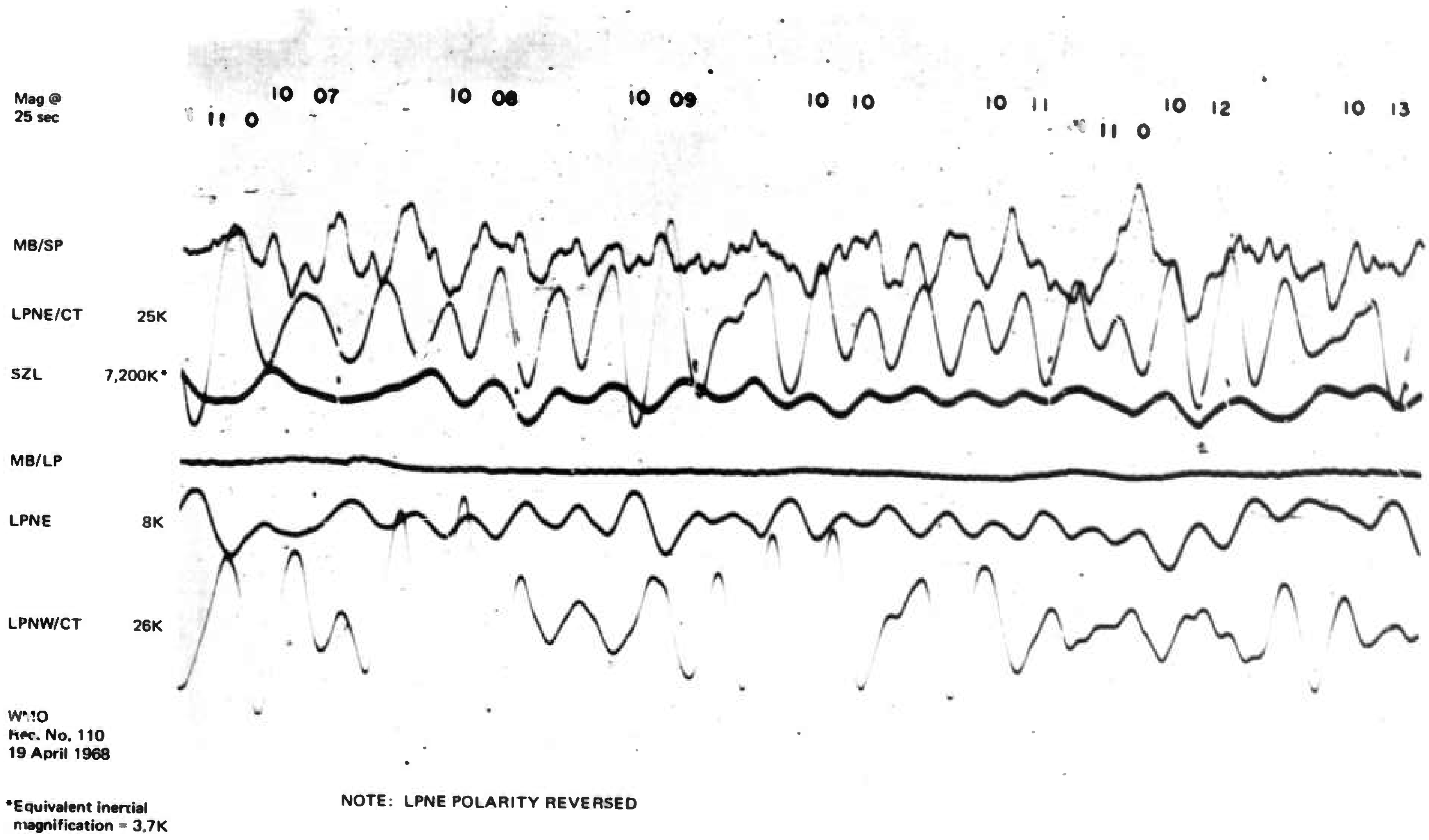


Figure 5. Seismogram of surface waves from a magnitude 5.6 earthquake demonstrating present degree of usefulness of SZL for studying large magnitude events. The earthquake is from the South Atlantic Ridge, 42.6S, 16.0W, 19 April 1968, 0 = 09 04 27.3, Δ = 108 deg., h = 33, m_b = 5.6 CGS

7. TEST NEW SITE (TASK 2c)

Early in the report period, plans were made for operation of a matched pair of vertical strain and inertial seismographs at Garland, Texas. Arrangements were firmed for use of the 107 m borehole at the Geotech facility starting 1 June 1968. A pier was made available for the inertial seismometer and two phototube amplifiers. The necessary instrumentation was procured and the operating parameters checked. Arrangements were made for use of the model station test facility to provide the necessary recording facilities.

On 24 May, the Project Officer ordered a hold on plans to operate at Garland. Grapevine was again considered on the chance that the vertical strain seismometer could be modified to fit in the smaller diameter boreholes at that site; however, it was concluded that it would be impractical to modify the seismometer. Meanwhile, a decision was made to seek a site with a higher noise level at 1 Hz and a lower level of cultural noise at higher frequencies. Consideration was given to operation at Fort Stockton, Texas; Houlton, Maine; and Cumberland Plateau Observatory (CPO), McMinnville, Tennessee. Consideration was given to character of the seismic noise, availability of a borehole, and operating costs. Budgetary cost estimates on borehole preparation and operational costs at Grapevine, Fort Stockton, COP, and Houlton were furnished the Project Office on 29 May 1968.

Additional sites with suitable boreholes probably exist. However, they would have to be located, the borehole alignment measured; a noise survey run; lease arrangements made; and recording facilities and manpower furnished to operate the equipment. A budgetary cost estimate for locating, surveying, and leasing an additional site was also furnished the Project Office on 29 May 1968.

8. REFERENCES

Bendat, Julius A., and Piersol, Allen G., 1966, Measurement and analysis of random data: New York, John Wiley and Sons, Inc., p 215-216.

APPENDIX 1 TO TECHNICAL REPORT NO. 68-22

STATEMENT OF WORK TO BE DONE
(AFTAC PROJECT AUTHORIZATION NO. VELA T/8704/S/ASD)

F33657-68-C-0948

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/8704/S/ASD)

Tasks:

1. Operation:

a. Routinely operate and maintain the short-period multicomponent strain seismograph system, and the companion pendulum seismographs, at the Wichita Mountains Seismological Observatory (WMSO).

b. Record seismic data on film and magnetic tapes. Establish a library of seismic data, including records of background noise and signals and appropriate identifying logs, suitable for use in this and other projects.

c. Evaluate the seismic data collected to determine optimum operating characteristics and adjust the instrumentation accordingly. Establish procedures and maintain quality control to assure collection of high-quality data.

2. Analysis and Investigations:

a. Analyze data from the strain- and pendulum-seismograph systems to demonstrate further the application of strain seismograph systems to seismic detection and identification problems. This analysis should include, but not necessarily be limited to, the following:

(1) Investigate the use of multiple-strain/pendulum-input processes for suppressing complex noise fields.

(2) Study the usefulness of strain- and strain/pendulum-seismograph systems for identifying various types of seismic waves.

(3) Study the usefulness of strain- and strain/pendulum-seismograph systems in distinguishing between seismic signals from earthquakes and explosions.

b. Investigate the characteristics and limitations of existing instrumentation and determine possible improvements. Recommend and make modifications as approved by the project officer.

c. Install and operate a vertical strain seismograph with a companion pendulum seismograph at Garland, Texas.

Operate the installed instruments for a period of nine months and demonstrate the extent of P-wave signal enhancement possible with the strain-pendulum combination,

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REPORT OF PROGRESS AGAINST SELECTED MILESTONES
(See instructions on reverse before filling in)

1. ARPA ORDER NUMBER: 624

2. PROJECT: Short-Period Multicomponent Strain System

3. COMPONENT:

4. NAME AND LOCATION OF PREPARING ACTIVITY:
Teledyne Industries Inc., Geotech Division
3401 Shiloh Road, Garland, Texas

5. CONTRACT NUMBER: F33657-68-C-0948

6. REPORT FOR MONTH ENDING: 31 May 1968

CODE a	MILESTONE b	SCHEDULED COMPLETION DATE c	ESTIMATED COMPLETION DATE d	DATE COMPLETED e	REMARKS f
2	No. 1 Install new electromagnetic calibrators on all strain seismometers at WMO.	31 July 1968			
2	No. 2 Install a vertical strain seismograph and a companion inertial seismograph at Garland, Texas.	31 July 1968			

TYPED NAME AND TITLE	SIGNATURE	TELEPHONE	DATE SIGNED
Robert C. Shopland Senior Project Physicist	Robert C. Shopland	214 271-2561	15 June 1968

SD FORM 1 JAN 55 350

Unclassified
CLASSIFICATION

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Geotech, A Teledyne Company 3401 Shiloh Road, Garland, Texas 75040	2a. REPORT SECURITY CLASSIFICATION 2b. GROUP

3. REPORT TITLE

Short-Period Multicomponent Strain System
Quarterly Report No. 1, Project VT/8704

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

15 February to 31 May 1968

5. AUTHOR(S) (First name, middle initial, last name)

Robert C. Shopland

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
15 June 1968	26	1

8a. CONTRACT OR GRANT NO. F33657-68-C-0948 b. PROJECT NO. VELA T/8704 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report No. 68-22 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Hq USAF (AFTAC/VELA Seismological Center) Washington, D. C. 20333

13. ABSTRACT

A five-component system of matched short-period strain and inertial seismographs at Wichita Mountains Observatory (WMO) was expanded to include a three-component system of matched long-period strain and inertial seismographs for recording large magnitude earthquakes. A data library and quality assurance procedure has been established. Calibration of the vertical strain seismometer with both a short rod and a rod of standard length (18 m) shows an apparent mechanical signal loss of 22 percent and a corresponding phase change as large as four degrees. A series of improvements has reduced the noise level of the long-period strain seismographs substantially. A site other than Garland, Texas, is being considered for noise suppression tests with a combination of vertical strain and inertial seismographs. From a recent study of the effect of low ratio of seismic signal to system noise on coherence, it is concluded that the possibility of suppressing microseisms in the region of 1 Hz with a combination of vertical strain and inertial seismographs cannot be evaluated unless either the generator constant of the vertical strain seismometer is increased, or tests be conducted at a site where the seismic noise level at 1 Hz is higher than at WMO.

DD FORM 1 NOV 65 1473

Unclassified

Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Seismology						
Strain seismographs						
Strain applications						

Security Classification